Interactions between Visuospatial Attentional Demands and Working Memory Load while driving

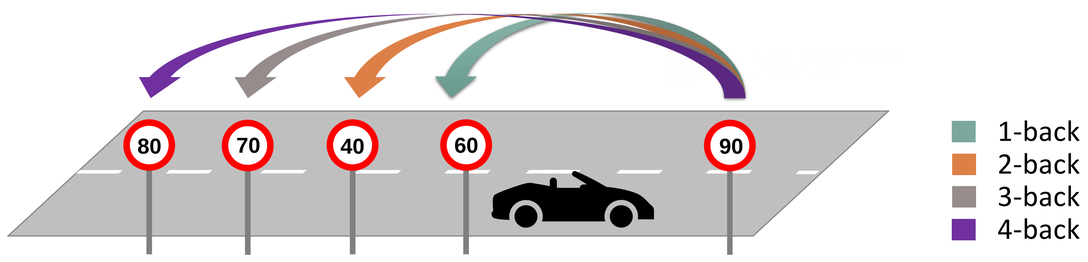
Moritz Held[1,2], Jelmer Borst[1], Anirudh Unni[2], Jochem W. Rieger[2]

[1]University of Groningen, Bernoulli Institute | Department of Artificial Intelligence
[2]University of Oldenburg, Department of Psychology | Department of Applied Neurocognitive Psychology

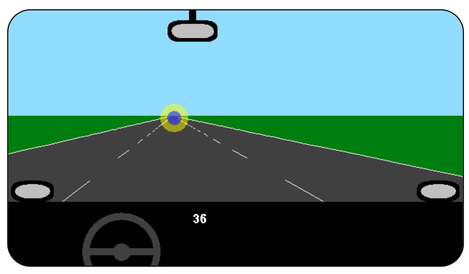
Introduction

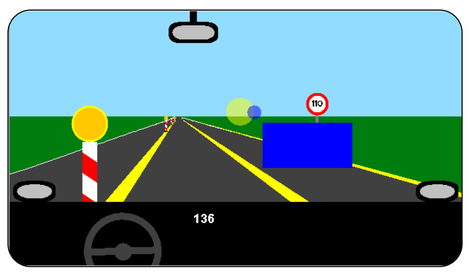
A long-held belief in autonomous driving research is that more automation will equate more safety. A contrary approach is adaptive automation, which in the context of driving describes an interactive man-machine system that adapts the level of intervention by the machine depending on the momentary cognitive load of the driver. To realize such a system, the cognitive workload must be able to be predicted while driving. Attempting this, Unni et al. (2017) and Scheunemann et al. (2019) found an interaction between the cognitive concepts working memory load (WML) and visuospatial attention while driving. We adapted the driving model by Salvucci (2006) to investigate this interaction.

Experimental Design

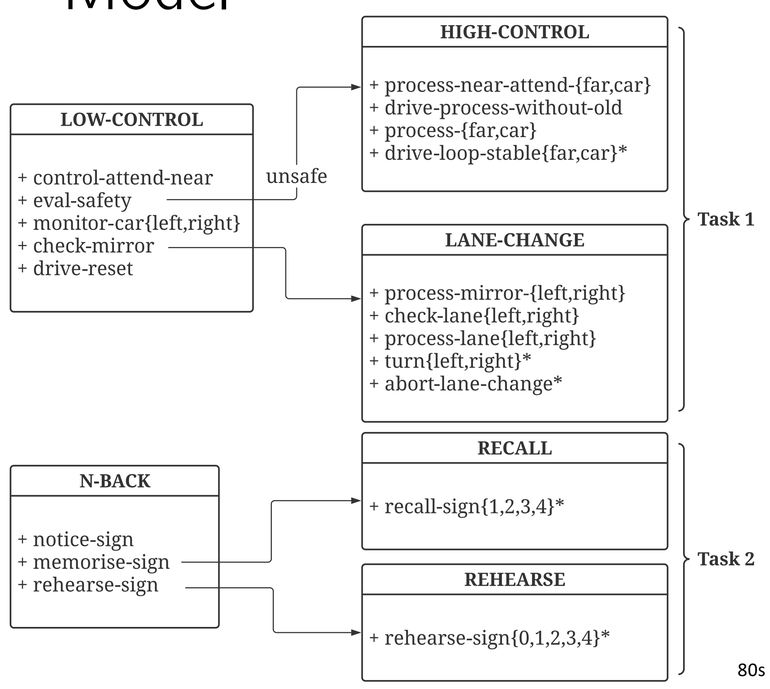


- Threaded cognition (Salvucci & Taatgen, 2008) predicts a bottleneck at the central processing unit
- Highway: 3.5m lane-width, 3 open lanes
- Construction: 2.5m lane-width, left lane blocked off
- Model must maintain safe position on road while driving a speed dictated by the modified n-back task



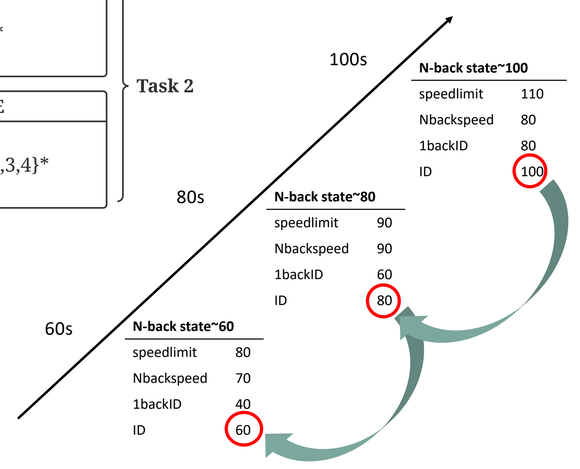


Model

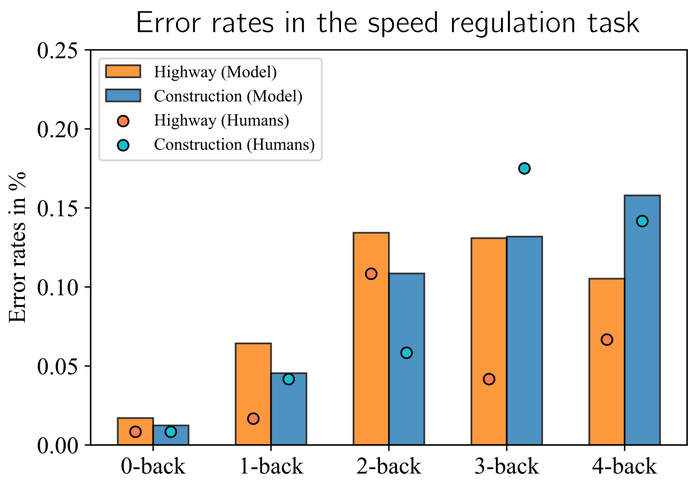


- Sequential memorizing and recall
- Errors modeled by partial matching
- Rehearse sequence up to three times

- Low-control loop when driving in a safe position of the road
- High-control loop when nearing the lane-edges to steer back to center

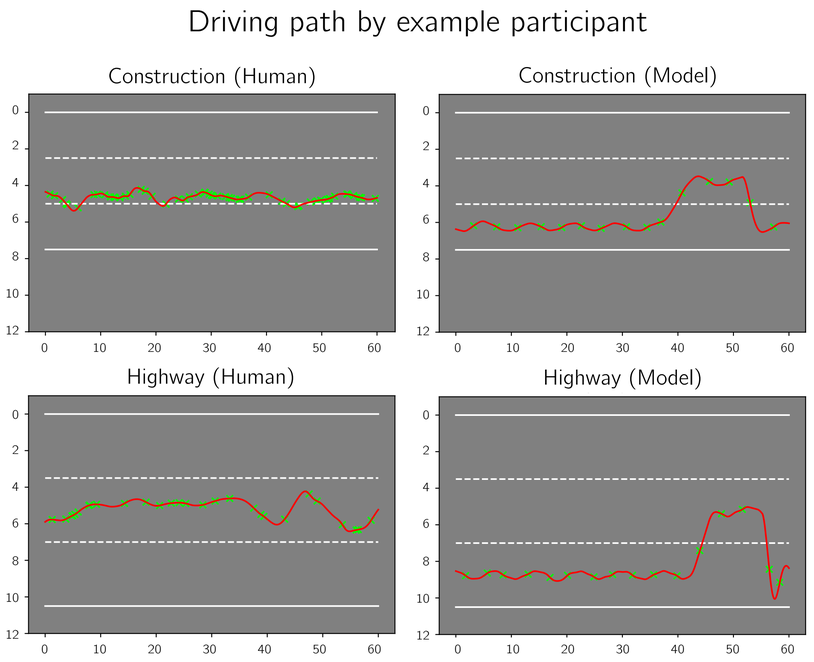


N-back performance

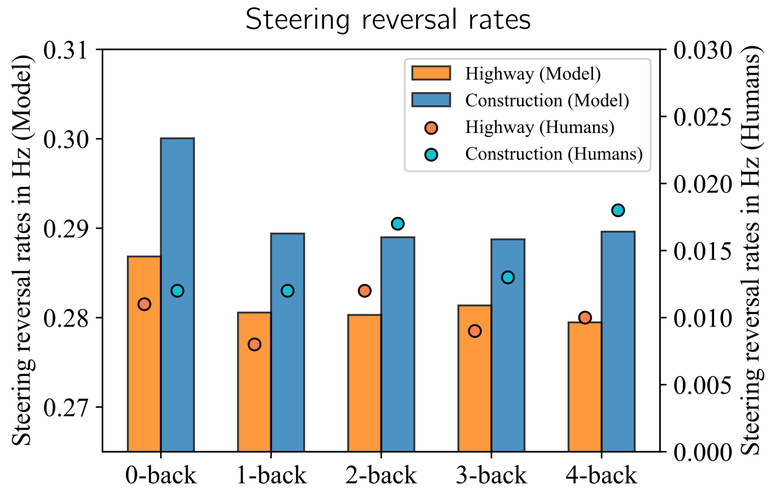


- Increase in error-rate with n-back level
- Model does not predict higher error rates in either visuospatial condition
- Increase in error rates slows down in higher n-back levels

Driving behavior



- Differences in steering reversal rates are likely underestimated by the model
- Humans make more minute changes to steering in construction site



- Slight decrease in steering reversals with increasing n-back level
- Increased steering reversals in the construction condition compared to normal highway driving

Conclusion

- The model is able to show how both tasks compete for available resources as driving behavior is influenced by n-back level
  → contention of resources to procedural memory by the central processing unit
- The model shows increased steering reversal rates in the construction condition.

Limitations and open questions

- Some model parameters had to be estimated due to lacking data
- We are analyzing new data from a study with human participants giving further insight into workload and visual demands using eye-tracking
- How does increasing the visuospatial demands impact speedometer checks?
- Do recall and rehearsal strategies remain consistent over n-back levels?

References:
Salvucci, D. D. (2006). Modeling driver behavior in a cognitive architecture. Human Factors, 48(2), 362–380. https://doi.org/10.1518/001872006777724417
Salvucci, D. D., & Taatgen, N. A. (2008). Threaded Cognition: An Integrated Theory of Concurrent Multitasking. *Psychological Review, 115*(1), 101–130. https://doi.org/10.1037/0033-295X.115.1.101
Unni, A., Ihme, K., Jipp, M., & Rieger, J. W. (2017). Assessing the driver's current level of working memory load with high density functional near-infrared spectroscopy: A realistic driving simulator study. Frontiers in Human Neuroscience, 11, 167. https://doi.org/10.3389/fnhum.2017.00167
Scheunemann, J., Unni, A., Ihme, K., Jipp, M., & Rieger, J. W. (2019). Demonstrating Brain-Level Interactions Between Visuospatial Attentional Demands and Working Memory Load While Driving Using Functional Near-Infrared Spectroscopy. Frontiers in Human Neuroscience, 12, 542. https://doi.org/10.3389/fnhum.2018.00542

STAY UP TO DATE:

moritz.held@uol.de